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TASK OBJECTIVES

Most of the effort during the first half of this year was spent in preparation for the Vegetation Index ATBD Peer Review in May and the IGARSS' 94 Symposium scheduled for August 1994 in Pasadena. Also a research agenda for summer field activities in Arizona, Portugal, and Mexico related to product validation was established. In the laboratory, we continued further work in analysis and comparisons of various vegetation indices (VI's) utilizing Landsat TM, ASAS, AVIRIS, and AVHRR derived imagery. Analyses of the BRDF characteristics of desert to forested biomes were initiated for integration into the level 3 VI compositing algorithm.

WORK ACCOMPLISHED

1. Vegetation Index ATBD Peer Review

Five reviewers evaluated the MODIS Vegetation Index ATBD-MOD-14, with only 1 reviewer remaining anonymous. The written reviews were very favorable with 2 A's and 2 B's and the anonymous left blank. The VI-ATBD involves two indices; (1) the NDVI for purposes of continuity; and (2) a modified NDVI or MNDVI, representing an improved version of the NDVI. The strengths of the ATBD concerned the attempt to minimize atmospheric and canopy background effects while maintaining vegetation sensitivity. Providing some form of continuity with the NDVI also received favorable responses. The main weakness was a lack of validation of the proposed modified NDVI (MNDVI) and the need for a more thorough analyses on the multitemporal compositing scheme for the two VI's.

In the oral presentation TM and ASAS images illustrated the improvements made by the MNDVI relative to the NDVI. The MNDVI displayed a greater contrast of vegetation conditions and was not confused by shadow influences. In comparison, the NDVI interpreted canopy shadowed areas as photosynthetic and saturated early under medium vegetation densities. Graphical simulations were also used to demonstrate reduced error and uncertainties due to soil and atmosphere in the MNDVI.

The ATBD review panel had additional concerns, including the need for an atmospheric resistant component assuming that an operational atmospheric correction scheme will be implemented. As discussed in the ATBD document, it is doubtful that an operational atmospheric correction can be applied consistently on a global basis. It is more likely that a dark object subtraction will be performed in certain areas and a mean sky climatology approach implemented in other regions where dark objects are unavailable. This may alter the integrity of the vegetation index and thus it

was felt that an atmospheric resistant component could only help the VI. The other issue concerns validation. The review panel recommended that more emphasis be placed on biophysical coupling of the VI to plant parameters such as APAR and LAI.

2. SCF Activities

2.1. Walnut Gulch, ASAS Data

Hongyan Liu (Ph.D. candidate) is processing ASAS imagery acquired during the dry and wet seasons of 1991 over the Walnut Gulch Experimental Watershed in southeastern Arizona. The 7 multiple view angle imagery along both principal and orthogonal planes to the sun, at both large and small solar zenith angles, were acquired over a semi-desert grassland site (Kendall), a mixed grass-shrub site (Gleeson), and a Riparian forest - Mesquite bosque site along the San Pedro river. The 29 band data were reduced to the first 4 MODIS bands from which various VI's were computed. With the aid of concurrent atmospheric measurements made with a sun-tracking solar radiometer and the 6S' radiant transfer program, total and partial (Rayleigh and ozone) atmospheric correction of the ASAS scenes were accomplished.

The multi-view, bidirectional reflectance profiles were analyzed as functions of land cover type, dry vs. wet season, atmospheric condition, and sun angle. The main objective of this work was to investigate the directional effects of the individual bands and the different VI's calculated from MODIS bands. The normalized view angle profiles showed greater sensitivity to external conditions (atmosphere and sun angle) than to vegetation type. The shape of the view angle profile was also more a function of the VI used than the vegetation type. Major sections of this work will be presented at the IGARSS'94 Symposium at a special ASAS session.

2.2. U.S.A - Mexico Thematic Mapper Data

Gerardo de Lira (a Ph.D candidate) continues to work on the 1992 Landsat TM imagery acquired over the Arizona-Sonora border. All 8 images were co-registered and a Rayleigh and ozone atmospheric correction performed. Spatial and temporal variations across the border are quite distinct with the Mexican side containing higher reflectance values and lower NDVI and MNDVI values. The sites sampled included: grassland, shrubland, degraded mesquite- grassland, riparian zones, and conifer covered mountain areas. Over some of the sites, the spatial variability was too great to clearly document border differences, however, image based analyses quite clearly showed the border and the accompanying differences on both sides.

The multi-temporal analysis demonstrated that the border differences remained throughout the year but the vegetation index values were fairly similar during the dry season. Brightness temperature differences were also relatively small across the

border for most of the year. The results of this work will be presented at the IGARSS' 94 Symposium on August 8-12, 1994, in Pasadena, California.

A multi-temporal mixture model will also be applied to this data set for land cover discrimination studies in support of the MODIS Land Cover and Land Cover Change algorithms.

2.3. TM Calibration Coefficients

Hui Qing Liu (research specialist) is testing different sets of Landsat 5 TM calibration coefficients on the vegetation index product. Some of the more recent, vicarious-based, calibration coefficients, derived at White Sands, New Mexico and Maricopa Agricultural Center in Arizona (Slater, personal communication) contain significantly different slopes producing differences in VI imagery. In some cases the new calibration coefficients result in topographically sensitive NDVI values. Although it is difficult at this time to assess the accuracies of the various sets of coefficients, it is important to note and document VI sensitivity to radiometric calibration drift and error.

2.4. OTTER ASAS Data

Hui Qing Liu has also processed large sets of OTTER ASAS and OTTER NS001 TMS into MODIS band and VI imagery. This was primarily done to incorporate a wider range of land surface vegetation conditions in the VI evaluation and validation process. Different NDVI variant equations were tested under various sun angles, atmospheric conditions (Rayleigh and ozone corrected), and viewing angles in the case of the ASAS data. Eight sets of images including 7 view angles were analyzed for the OTTER ASAS and 14 scenes for OTTER NS001 TMS.

The ASAS results are being used to analyze bidirectional view angle profiles of forested canopies in both the principal and orthogonal planes to the sun. In the orthogonal plane, the NDVI, SAVI, and MNDVI were symmetric about nadir viewing angles, but along the principal plane the NDVI was found to be biased (or higher in value) in the forward scatter direction while the SAVI was biased in the antisolar view direction, and the MNDVI remained symmetric about nadir with increasing values with higher view zenith angles.

In the NS001 data, VI results are being compared with published ground based LAI measurements. The saturation of the higher LAI forests were clearly seen in the NDVI results, whereas the other VI's continued to vary with increasing LAI values.

2.5. NIGER-HAPEX ASAS Data

Wim van Leeuwen, a Ph.D. student is integrating his biophysical and field radiometric measurements acquired at HAPEX-Sahel with concurrently acquired 1992 ASAS imagery. He is

attempting to model ASAS pixel responses with in-situ hemispherical reflectance factors of "pure components" (leaf, soil, bark, etc), measured with an integrating sphere, and combined with the SAIL model to generate canopy (structural) spectra at varying LAI conditions. He is also utilizing field measured spectra of the canopies for the same purpose. Linear and non-linear spectral mixture models are then being used to invert the "mixed" spectral responses of a target into the vegetated spectral components for each of the subsites in the West-Central supersite. The objective of this work is to relate the decomposed components of a mixture model with known biophysical properties of the surface as well as to improve our understanding as to how non-photosynthetic optical components influence canopy spectra.

The SAIL- model generated vegetation-soil "mixtures" reflectances were used to create relationships with leaf area index and fraction of intercepted photosynthetically active radiation (FIPAR) for a range of vegetation densities. These results were then examined to determine if they could serve as a reference for the quantitative interpretation of the optical field data. The mixture model was applied to the simulated data and validated with observational ground data (LAI, IPAR and reflectance) measured at the HAPEX-Sahel bush/grassland fallow and millet sites.

The spectral mixture model was applied to subsets of a nadir image with and without atmospheric contamination, which resulted in quantified estimates of the abundance of vegetation and soils. The mixture model was applied to the complete 33 band ASAS data. Pseudo color maps of vegetation and soil abundance, LAI and fIPAR were produced.

2.6. Walnut Gulch Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data.

Karim Batchily (program coordinator) is involved in the processing of 1991 AVIRIS imagery acquired over the Walnut Gulch Experimental Watershed during the dry season of 1991. In collaboration with Dr. Erzsebet Merenyi of the Lunar and Planetary Lab at the University of Arizona, they are producing both neural-net and mixture model based classifications of the scene components which include semi-arid grassland, mixed grass-shrub, and desert shrub plant communities underlain by a complex pattern of soil types including basalts, and calcic and iron rich soils. This study is complimented with field radiometric measurements and an analysis of soil physical properties for validation of the mixture model. The spectral data will be integrated and compared with both ASAS and TM imagery over the same area for studies related to scale and spectral dimensionality analyses. We hope that this provides an opportunity to investigate the synergistic uses of multiple sensors for large scale soil and vegetation mapping.

2.7. AVHRR Study Sites

Hongtao Jin (Master's degree student) is working on the 1 km composited AVHRR data over North America and the 8 km daily AVHRR pathfinder data set to investigate the compositing procedure of the vegetation index and to study the multi-temporal behavior of VI data over a large range of land cover types. In particular, various sites of the Chinese Ecological Research Network (CERN) are being extracted with the 8 km AVHRR data to investigate the multi-temporal vegetation dynamics of these sites. Similarly, a climatic gradient of land cover types are being extracted from Africa for the same purpose. He is also comparing alternative compositing procedures involving the NDVI, SAVI, cloud cover, and sun-view geometries.

2.8. Myneni Radiative Canopy Model

José Epiphanio (Post-doctorate) is investigating the use of absorbed photosynthetically active radiation (APAR) and leaf area index (LAI) in growth and productivity models, with particular emphasis on surface heterogeneity of the vegetated surfaces. He is utilizing the Myneni canopy model, in conjunction with 6S' atmospheric radiative transfer model to simulate the optical properties of both uniform and heterogeneous vegetated surfaces. The optical data is being generated over a series of sun-view geometries and reduced to vegetation indices to study their dependence and sensitivity to the growth parameters, LAI and APAR. His results are being presented at the IGARSS'94 Symposium in Pasadena, August 1994.

FIELD ACTIVITIES

1. Portugal

From July 3 to July 16, field research was conducted in Portugal. This is part of a collaborative project established with Dr. José Pereira of the Universidade de Lisboa to obtain high resolution spectra of several Mediterranean vegetated biomes. Measurements were made above the forested canopy sites with a fire-truck operated ladder (30 m) with additional measurements made underneath the forest canopy. The ground-based measurements provided values of canopy transmittance and understory and/or background reflectances. This data will be used to validate the physical bases of some of the newer vegetation indices through an analyses radiative transfer within canopies, and an understanding of how forest backgrounds influence the VI's.

2. U.S-Mexico border

A field campaign is being planned for the wet season (monsoon period) along the U.S-Mexico border. Site locations involving the multitemporal TM data set have been established with the help of on-site ground verification. This project involves the University of Arizona and CIDESON in Hermosillo, Sonora Mexico. The objective of this study is to incorporate the results of the

satellite data set with more intensive ground measurements. Ground sites are in grassland, degraded mesquite - grassland, and along the San Pedroriparian areas.

3. Walnut Gulch field activities.

Activities are concentrated on continued vegetation and soil samplings in support of the ASAS, TM, and AVIRIS image data sets. These data will also be related to ERS-1 SAR and K- band airborne data scheduled to be acquired on July 25, 1994.

ANTICIPATED FUTURE ACTIVITIES

1. SeaWifs data processing

A limited amount of land-based SeaWifs data will be processed into vegetation index products for testing and comparison of the NDVI with the various NDVI variant equations. The GIMMS group at NASA/GSFC under the supervision of Chris Justice will process some of the SeaWifs data. The SeaWifs sensor will provide the blue band which will enable some of the atmospheric resistant components of the VI's to be tested on a global and regional basis.

2. 1 km AVHRR Pathfinder

In conjunction with the GIMMS group, the 1 km AVHRR data set being compiled by the EROS Data Center will be used for prototyping of some of the VI equations and for intensive analyses of the compositing procedure. This data set will allow us to assess the bidirectional influences of multiple view composited data and will also allow for testing of atmospheric processing scenarios.

3. Biophysical Coupling of the VI's

As a result of the ATBD Peer Review, more emphasis will now be placed in deriving biophysical products with the VI equations. This effort will be land cover type dependent and may involve a set of equations for each land cover type or biome. Field-based campaigns at the various Long Term Ecological Research (LTER) sites will enable experimental coupling of LAI and APAR with Landsat TM data, which will provide initial testing of the VI's. In addition BOREAS field and satellite data will be used. Finally, in conjunction with Steve Running's group, canopy simulation models will be incorporated such as the Myneni model.

4. IGARSS'94 Symposium papers

The following papers will be presented at the IGARSS'94 Symposium on August 8-12, 1994, in Pasadena, California:

i. A.R. Huete, H. Liu, G.R. de Lira, K. Batchily, and R. Escadafal, "A soil color index to adjust for soil and litter noise in vegetation index imagery of arid regions".

ii. W.J.D. van Leeuwen, A.R. Huete, and C.L. Walthall, "Biophysical interpretation of a spectral mixture model based on a radiative transfer model".

iii. G.R. de Lira, K. Batchily, J. Hongtao, and A.R. Huete, "Optical and seasonal variations along the U.S-Mexico border: an analysis with Landsat Thematic Mapper imagery".

iv. J.C.N. Epiphanio, A.R. Huete, and H. Liu, "Influence of sun-view geometries on the relationships among vegetation indices, LAI, and absorbed PAR".

v. H.Q. Liu and A.R. Huete, "A system based modification of the NDVI to minimize soil and atmospheric noise".

5. Other Papers to be Presented

A.K. Batchily, A.R. Huete, E. Merenyi, J. Hongtao, L. Accioli, and G.R deLira, "Extraction of soil information from remotely sensed semi-arid areas with mixture models", to be presented at the 1994 American Society of Agronomy (ASA) meeting in Seattle, Washington, Nov. 13-18.

Three papers are scheduled to be presented at the American Geophysical Conference (AGU) in San Francisco, Dec. 1994:

i. A.R. Huete and C. Justice, "Global based vegetation indices with SeaWifs".

ii. J.C.N. Epiphanio, A.R. Huete, "Effect of soil red and Nir contrast on vegetation indices".

iii. W. van Leeuwen, A.R. Huete, C.L. Walthall, "Atmospheric effects on the decomposition of spectral mixtures using ASAS imagery".

6. Meetings

i. I will attend an Inter-American Institute (IAI) "Workshop on Comparative Studies of Temperate Terrestrial Ecosystems" on July 26-29, 1994, in Durham, North Carolina. This workshop is hosted by the Inter-American Institute for Global Change Research. The objective of the workshop is the development of regional scientific plan to further global science research and impacts on natural and social systems.

ii. I will attend, by invitation, the "Second Workshop on Spectral Mixture Analysis" on August 15-17, 1994, at the University of Washington in Seattle. The objective of this

workshop is to compare state of the art' mixtures methodologies and assess future directions in mixture modeling.

iii. Wim van Leeuwen will attend a HAPEX-Sahel meeting in Toulouse, France on November 14-15, 1994.

iv. Along with Dr. Michel Verstraete of ISPRA, we will convene a joint Hydrology and Atmosphere session on the design and evaluation of spectral Indices at the next American Geophysical Union (AGU) meeting in San Francisco, California on Dec. 1994. The objective of the session is to further advance our understanding on empirical global-based approaches toward a biophysical understanding of terrestrial vegetated surfaces.

PUBLICATIONS

H.Q. Liu and A.R. Huete, "A feedback based modification on the NDVI to minimize soil and atmospheric noise". Submitted to IEEE Trans. Geosc. and Remote Sensing (4/94).

J.C. Epiphanio and A.R. Huete, "Dependence of NDVI and SAVI on sun/sensor relationships in alfalfa". Submitted to Remote Sensing of Environment (4/94).

Chehbouni, A., Kerr, Y.H., Qi, J., Huete, A.R., Sorooshian, S., 1994. "Toward the development of a multidirectional vegetation index." Water Resources Research 30(5):1281-1286.

Franklin, J., Duncan, J., Li, X., Huete, A.R., van Leeuwen, W.J.D., 1994. "Radiative transfer in a shrub savannah -- preliminary results from HAPEX-Sahel: 2. Modelling surface reflectance and vegetation indices using a geometrical-optical approach." Agric. and Forest Meteorology (in press).

Huete, A.R., Liu, H., 1994. "An error and sensitivity analysis of the atmospheric- and soil-correcting variants of the NDVI for MODIS-EOS." IEEE Trans. Geosc. and Remote Sensing, Vol. 32: (in press).

Huete, A., Justice, C., Liu, H., 1994. "Development of vegetation and soil indices for MODIS-EOS." Remote Sensing Environment 48:1-13.

Moran, M.S., Clarke, T.R., Kustas, W.P., Bach, L., Weltz, M., Amer, S.A., Huete, A.R., 1994. "Evaluation of hydrologic parameters in semi-arid rangeland using remotely sensed spectral data." Water Resources Research 30(5):

Qi, J., Huete, A.R., Cabot, F., Chehbouni, A., 1994. "Bidirectional properties and utilizations of high resolution spectra from a semi-arid watershed." Water Resources Research 30(5):1271-1279.

Qi, J., Chehbouni, A., Huete, A.R., Kerr, Y.H., Sorooshian, S., 1994. "A modified soil adjusted vegetation index: MSAVI." Remote Sensing Environment (in press).

van Leeuwen, W.J.D., Huete, A.R., Duncan, J., Franklin, J., 1994. "Radiative transfer in shrub savannah sites in Niger -- preliminary results from HAPEX-Sahel: 3. Optical dynamics and vegetation index sensitivity to biomass and plant cover." Agric and Forest Meteorology (in press).

Manuscripts in Preparation:

A.R. Huete, W. van Leeuwen, A. Strahler, and C.L. Walthall, "BRDF modeling of HAPEX ASAS imagery for vegetation index composites". Manuscript in preparation for the special issue of results for HAPEX-Sahel in the journal of Hydrology, October 1994.

W.J.D. van Leeuwen, A.R. Huete , C.L. Walthall, "Mapping of vegetation and soil parameters using ASAS imagery from HAPEX-Sahel". Manuscript in preparation for the special issue of results for HAPEX-Sahel in the journal of Hydrology, October 1994.

S.D. Prince, N.P. Hanan, A. Begue, A. Huete, J. Franklin, W. van Leeuwen, and J. Duncan, "Remote sensing of primary production in HAPEX-Sahel". Manuscript in preparation for the special issue of results for HAPEX-Sahel in the journal of Hydrology, October 1994.